I-SEM Capacity Mechanism:
Consultation on Additions and Modifications to the Capacity Requirement & De-rating Factor Calculation Methodology

March 2018

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2 Executive Summary

On the 8th December 2016, the SEM Committee published an I-SEM CRM Capacity Requirement and De-rating Methodology Decision Paper (SEM-16-082), which included a commitment that the methodology for storage units will be consulted upon as part of the broader consultation prior to the first auction after the first transitional auction. This paper serves to fulfil this commitment.

The document SEM-17-040b, published in July includes an outline of the methodology for determining the De-rating Factors (DRF) for generator units with energy storage, which is expanded on in this paper. Additional issues relating to the calculation of De-rating Factors for storage units are also examined.

This paper also considers how a limitation to run hours[1] should impact on the calculation of a unit's de-rating factor.

The following questions are posed to stakeholders:

A. **Do participants have any comments on the methodology for calculating DRFs for storage units as described in this paper?**
B. **In the absence of significant historical data, do participants consider it reasonable to apply system-wide outage statistics to new technologies (such as batteries)? If not, please provide alternative with justification.**
C. **Regarding Storage Units with Storage Volume sizes that are not a multiple of 30 minutes: Do participants have any comments on the TSO's preferred methodology for calculating DRFs for such storage units, i.e. interpolating between storage sizes? What other options do they believe may be more appropriate?**
D. **Should storage units be allowed to apply a DECTOL to their De-rated Capacity? Please provide arguments to support your response.**
E. **Should specific DRF values be published for units with energy storage volumes of 6.5 hours or greater? Are participants aware of potential projects that might make such a change appropriate?**
F. **Do participants consider that a unit's run-hour limitations (due to emission restrictions or otherwise) should be reflected in the Capacity Market Auction? If so, what mechanisms should be applied. If not, please provide rationale.**
G. **Do participants have any comments on the proposed approach for de-rating DSUs with limited Maximum Down Time?**

[1] E.g. due to emissions restrictions, or approaching end of life

3 Introduction

3.1 Background

On 16th December 2015, the SEM Committee (Decision Paper SEM-15-103) asked the TSOs to develop the analytical methods to calculate the Capacity Requirement and De-rating Factors (DRF) for the Capacity Market. On the 8th December 2016 the SEM Committee published an I-SEM CRM Capacity Requirement and De-rating Methodology Decision Paper (SEM-16-082), which included a commitment that the methodology for storage units will be consulted upon as part of the broader consultation prior to the first auction after the first transitional auction. This paper serves to fulfil this commitment.

Appendix 1 of this decision paper (SEM-16-082a) was a TSO report on the methodology for the capacity requirement and de-rating factors for all units except for interconnectors. This was clarified in July 2017 by an amended version (SEM-17-040b). SEM-17-040b outlines the methodology for determining the de-rating factors for generator units with energy storage, which is expanded on in this paper.

In addition, this paper puts forward proposals on how a limitation to run hours[2] should impact on the calculation of a unit's de-rating factor.

[2] E.g. due to emissions restrictions, or approaching end of life

4 Calculating De-rating Factors for Storage units

4.1 Overall methodology

The methodology for the de-rating of generating units and demand side units is presented in SEM-17-040b. A summary of the process is outlined in Figure 1.

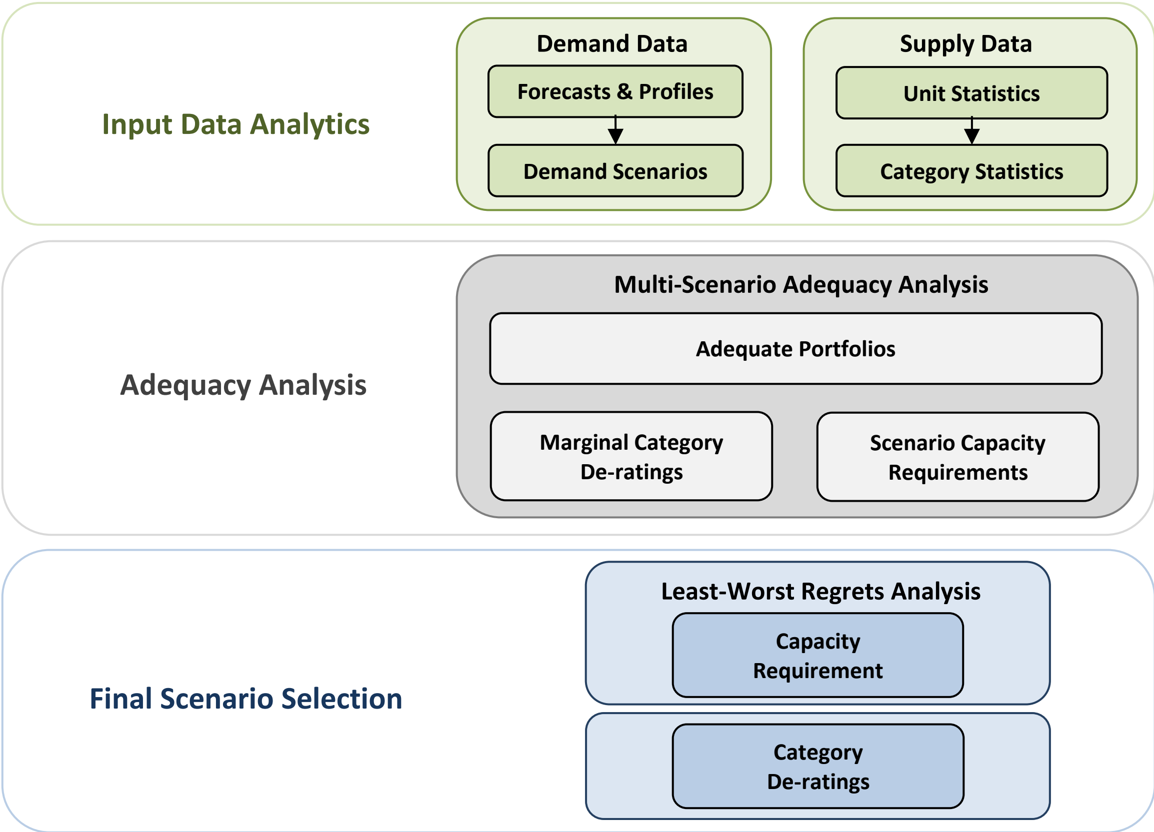

Figure 1: Conceptual Overview of the Capacity Requirement and De-rating Methodology

In the I-SEM Capacity Market, a marginal technology class de-rating factor is determined by looking at the impact on adequacy of adding a single notional unit of a specific technology class and size to capacity adequate portfolios for a demand scenario. The de-rating factor for that unit is calculated by dividing the MW increase in surplus caused by the addition of this unit by the MW size of that unit. This same process is followed for each technology class and each size class.

4.2 Complexities of storage

The marginal de-rating of storage units is more complex, as both the storage and generation component can vary in size. The generation component is treated as a load modifier (i.e. it reduces the peak demand until the associated reservoir is depleted) and replenishes the reservoir during the lowest demand periods. As the demand peak is increasingly flattened, fixed volumes of energy make less of an impact on the LOLE. It also becomes more difficult to refill the reservoir without raising LOLE in off-peak hours. This means that as the volume of storage on the system increases, its incremental contribution to reducing LOLE declines.

This can be seen in Figure 2, which shows four demand curves for a typical day in the SEM. As more storage is added, the height of the peak relative to the rest of the demand curve drops, and each incremental unit of storage becomes less beneficial from a system adequacy perspective. Meanwhile, the night valley fills up, and night-time demand starts to have a more noticeable contribution to the Loss of Load Expectation of the system.

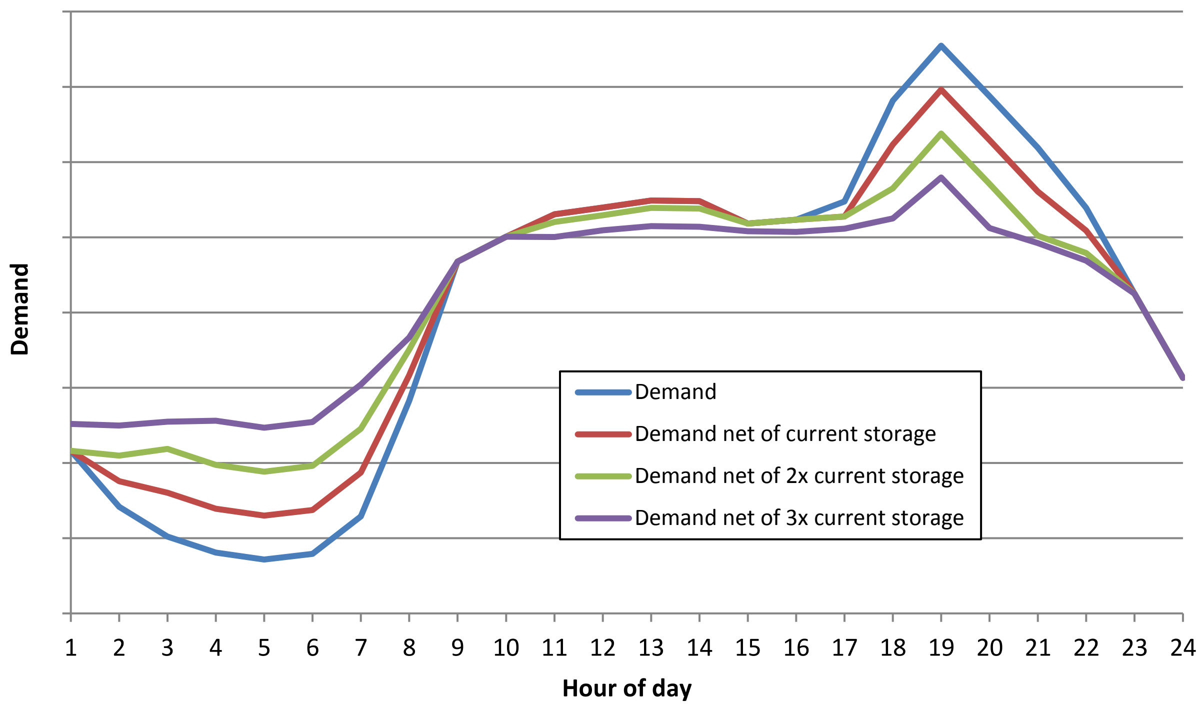

Figure 2. This graph shows demand curves for a typical day in the SEM. The blue line shows the original demand. The red line shows demand net of typical daily pumping and generation volumes of the current storage on the system (i.e. Turlough Hill). The green and purple lines show what net demand might be like if the current level of storage was doubled and tripled respectively.

The increase of night-time demand caused by storage units storing energy is a function of the conversion efficiency of storage units. It does not have a noticeable impact on system adequacy at present, and this is unlikely to change over the medium term barring a considerable increase in storage volumes on the system. As such storage efficiency assumptions are not discussed in this paper.

In the methodology presented here, De-rating Factors for storage units are given as a function of both generation sizes (measured in MW) and storage volumes (measured in hours). This is seen in the figure below, which graphs the De-rating Factors for Pumped Hydro storage units similar to those published in the Initial Auction Information Pack for the 2018/19 Capacity Auction.

Increasing a unit's generation capacity decreases its DRF, which is seen for all Technology Classes. However the impact of storage volume is more dramatic. As the storage volume of a unit decreases, its DRF drops rapidly. This can be seen in Table 1 of section 4.3.1, which shows DRF results from adding storage units of various generation sizes and storage volumes to the system.

For the Capacity Market, the de-rating factor determined for the existing level of storage on the system is to be used as a reference de-rating factor. Adequacy calculations tell us how much de-rated capacity we require to add or subtract in order to meet the LOLE standard. By removing existing storage as a whole from a portfolio, and noting the change in required capacity, we obtain the benefit of storage to the system based on the current level of storage installed on the system. This will give a de-rating factor off which all storage units will be assessed.

If new units have similar generation/storage abilities as the existing units they will get the same de-rating factor applied. If they are in a larger size class they will get a lower de-rating factor to account for their size and if they have less ability to sustain their generation, their de-rating factor will also be scaled accordingly. This scaling will be achieved by the use of a storage scaling factor.

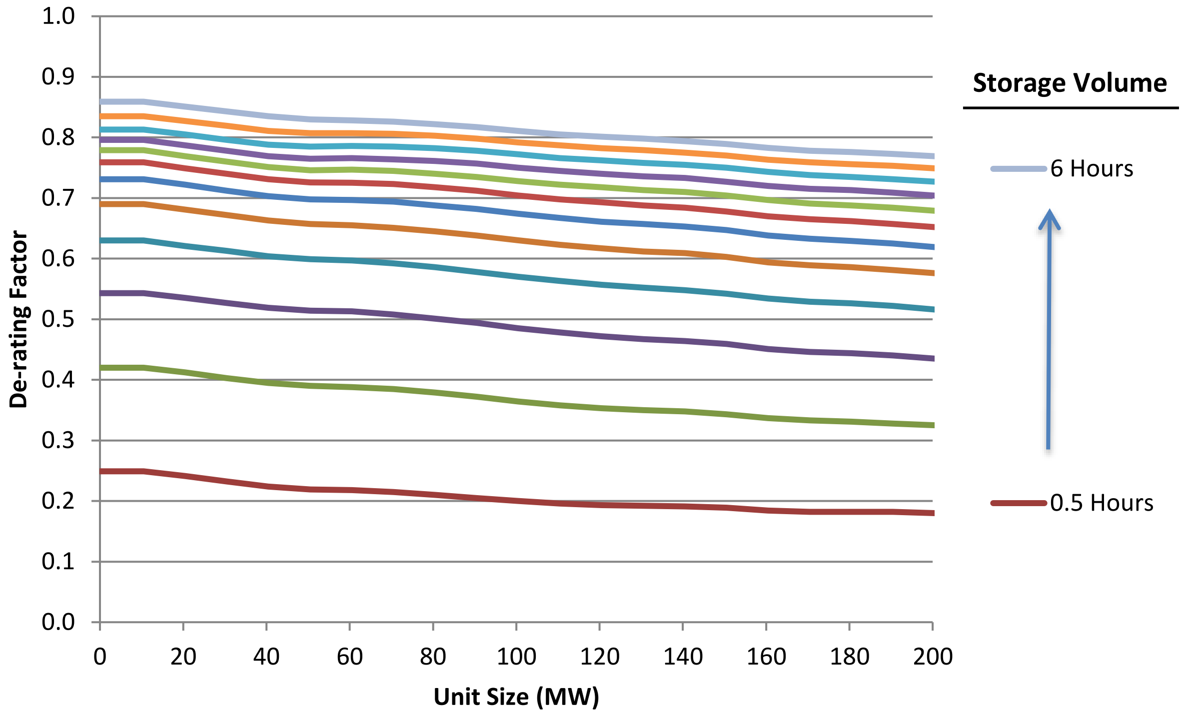

Figure 3. This graph shows the De-rating Factor curves for Pumped Hydro storage units. Each curve represents units with different storage volumes, going in half hour steps from 0.5 hours at the bottom to 6 hours at the top of the graph. The values used are based on those published in the Initial Auction Information Pack for the 2018/19 Capacity Market.

4.3 Proposed Storage Methodology

The methodology presented here proposes to calculate De-rating Factors for storage units as a function of both generation sizes and storage volumes. The generation sizes are given as the typical maximum output of a unit in MW, and are equivalent to Initial Capacity as described in the Capacity Market Code. The storage volumes are given as the maximum number of hours which all units sharing the energy storage (e.g. reservoir) can run simultaneously at their generation size, before the energy storage needs to be replenished. The methodology is split into 5 steps. These are summarised in the flow chart below, and expanded on in the paragraphs following that figure.

In essence, the methodology is similar to that used for non-storage units, with marginal DRFs calculated by adding a unit to a Capacity Adequare Portfolio (CAP) and noting the change in adequacy. However, treating existing storage units as if they were new leads to them being undervalued from an adequacy persepective.

To counteract this, the DRFs for storage are increased, so that their DRF is as if they were a component of the existing storage on the system. This increase is determined by the increase in adequacy of adding the existing storage to a system with no storage units. This ensures that the Final DRFs that apply to existing storage units will closely reflect their contribution to system adequacy.

Two sets of DRFs are published for storage units. The DRFs that apply to Pumped Hydro Storage units are based on outage characteristics that are calculated using the existing pumped hydro units on the system (currenly four Turlough Hill units). Due to the small number of existing Pumped Hydro Storage units, up to 10 years of historical outage data are used, rather than the 5 years used for other categories. For Other (i.e. non-Pumped Hydro) Storage, the DRFs are calculated using outage characteristics based on the system average, since no historical outage data is available. As with conventional units, should enough historical outage data become available, the RAs may define a new Storage Technology Class and request the TSOs to calculate the appropriate DRFs.

1. Calculate Initial Marginal DRFs for a range of generation sizes and storage volumes.

These are obtained by adding a range of units to an existing portfolio and noting the change in adequacy

2. Calculate the DRF of all Existing Storage **(DRF_{Ex})**

The DRF for Existing Storage is obtained by removing all storage from the existing portfolio and noting the change in adequacy

3.Calculate the DRF of the Reference Storage Unit **(DRF_{Ref})**

The Reference Storage Unit represents the average storage unit already on the system. Its DRF is read from the Initial Marginal DRF table.

4. Calculate Storage Adjustment Factor

Storage Adjustment Factor = DRF_{Ex}/DRF_{Ref}

5. Calculate Final Storage DRF values

Mulitiply Initial Marginal DRFs by the Storage Adjustment Factor. This gives the Final DRF values.

Figure 4 Five steps followed in order to calculate the Final DRFs for storage units

1. Calculate Initial Marginal DRFs

To calculate Initial Marginal DRFs, storage units with varying generation sizes and storage sizes are added one by one to each Capacity Adequate Portfolio (CAP). The CAP includes the existing storage units on the system. Only CAPs which are at the demand level identified by the Least-Worst Regrets Analysis are considered[3].

Adding a unit to the system increases the amount of 'surplus' de-rated generation the system has, compared to what is required to meet the 8 hours LOLE adequacy standard. The change in surplus that occurs due to the addition of the unit will be divided by its MW generation capacity to give

[3] See SEM-17-040b for more information on Demand Levels and the Least-Worst Regrets calculation

the marginal DRF for that generation size and storage volume combination. The values obtained for each CAP are then averaged.

2. Calculate the DRF of all Existing Storage (DRF_{Ex})

The contribution of Existing Storage to system adequacy is represented by the term $\mathbf{DRF_{Ex}}$. This value is calculated by removing existing storage from each CAP used in Step 1, and noting the change in surplus – this time we will have less de-rated capacity than required, so the surplus will be negative. The absolute change in surplus is divided by the capacity of Existing Storage. The values obtained for each CAP are then averaged to give $\mathbf{DRF_{Ex}}$.

Only units with a size of 10 MW or greater are considered as part of the Existing Storage, in order to be consistent with the calculation of DRF_{Ref} in Step 3.

3. Calculate the DRF of the Reference Storage Unit (DRF_{Ref})

Next, a DRF is obtained for a Reference Storage Unit representing the existing storage on the system. This value is called $\mathbf{DRF_{Ref}}$. This Reference Storage Unit is given the same generation capacity as the average of the existing significant storage units, and a storage volume given as the total storage from sizeable units on the system, divided by its generation size. Only units with a size of 10 MW or greater are considered when creating the Reference Storage Unit, as including smaller unit sizes could lead to an average unit that misrepresents the impact of storage on the system.

We assume that this unit takes the outage statistics of the storage type that makes up the majority of its capacity. This is currently Pumped Hydro Storage, however this can be reviewed as the mix of storage units on the system changes.

The value $\mathbf{DRF_{Ref}}$ can be obtained by adding the Reference Storage Unit to each CAP and noting a change in surplus. However this has already been done in Step 1. As such $\mathbf{DRF_{Ref}}$ can be obtained from the table of Initial Marginal DRF values, by looking up the Initial DRF for a unit with the generation size and storage volume of the Reference Storage unit.

4. Calculate Storage Adjustment Factor

The Storage Adjustment Factor, used to translate the Initial Marginal DRFs to a base level set by the existing storage capacity, is calculated as $\mathbf{DRF_{Ex}/DRF_{Ref}}$**.** It should always be greater than 1, since as the volume of storage on the system increases, its incremental contribution to reducing LOLE declines (see section 4.2).

5. Calculate Final Storage DRF values

The final step is to multiply the Initial Marginal DRFs (calculated in Step 1) by the Storage Adjustment Factor (calculated in Step 4). This gives the Final DRF values.

Referencing the DRFs to the existing storage units can be considered an unbiased approach for storage generation, since there is no 'preferential treatment' given to existing units compared to new units. It will tend to over-estimate the benefit of new storage to system adequacy. This is reasonable where there is only a small increase in the level of storage in a given auction. However if the TSOs become aware of significant quantities of new storage generation looking to connect to the system then this approach may need to be reviewed.

One might question why $\mathbf{DRF_{Ref}}$ is based on the average existing storage unit, rather than the total existing storage. The reason is that each component unit of the existing storage enters the auction separately, so the Storage Adjustment Factor (calculated in Step 4) needs to reflect this. If $\mathbf{DRF_{Ref}}$ was based on a single unit representing the total existing storage, the Storage Adjustment Factor would be too high when applied to the DRF for smaller individual units. This would lead to the sum of the de-rated capacity for existing storage units being greater than the actual benefit of the total existing storage.

There is a risk that, as the component units that comprise the existing storage change, the average existing storage unit may become less representative for certain component units on the system. This could happen if the existing storage comprises of a variety of unit sizes. This could in turn lead to the sum of de-rated capacities for existing storage units being higher or lower than the actual benefit of existing storage. If this were to happen, the approach described above may need to be reviewed.

4.3.1 Sample Calculation

For the Initial Auction Information Pack (IAIP), two storage DRF tables are produced; one for Pumped Hydro Storage units, and another for Other Storage units. This example shows how the DRF table for Pumped Hydro Storage units is calculated, however the calculation for the Other Storage table is very similar.

Consider an existing system which contains the following storage units:

i. Four pumped hydro units, each of 73 MW generator size, sharing a reservoir of 1500 MWh
ii. A single battery unit, generation size 10 MW, with a storage volume of 10 MWh
iii. A single battery unit, generation size 1 MW, with a storage volume of 2 MWh

Immediately, it can be seen that the smaller battery (iii) is too small to be considered in the calculation of $\mathbf{DRF_{Ex}}$ and $\mathbf{DRF_{Ref}}$. The example therefore ignores this unit and focusses on the significant storage units i.e. the four pumped hydro units and the larger battery (i and ii).

1. First, we get the Initial Marginal De-rating Factors for Pumped Hydro Storage by adding units of fixed storage and generation sizes. We note the change in system adequacy and divide by the unit generation size. For this example, we assume this gives the following table of de-rating factors for Pumped Hydro Storage:

Table 1 Initial Marginal De-rating Factors for Pumped-Hydro storage units

Units Size	0.5 Hours	1 Hours	1.5 Hours	2 Hours	2.5 Hours	3 Hours	3.5 Hours	4 Hours	4.5 Hours	5 Hours
20	0.205	0.354	0.462	0.536	0.588	0.623	0.647	0.665	0.680	0.696
40	0.191	0.339	0.448	0.522	0.572	0.607	0.631	0.649	0.665	0.681
60	0.189	0.337	0.445	0.518	0.569	0.605	0.630	0.649	0.666	0.684
80	0.181	0.327	0.433	0.506	0.558	0.596	0.622	0.642	0.660	0.679
100	0.171	0.313	0.418	0.492	0.544	0.582	0.609	0.630	0.649	0.668

A similar table is also created for Other Storage units.

2. Next, we calculate the de-rating factor for Existing Storage ($\mathbf{DRF_{ex}}$). To do this we remove all of the significant storage units from the system, and note the change in surplus. This value is called $\Delta SURP_{ex}$, and is given in MW. In this example, $\Delta SURP$ = 229 MW, meaning that the existing storage units are worth the same capacity as a standard (non-storage) 229 MW generation unit that has 100% availability.

We define **DRF_{ex}** as follows:

$$DRF_{ex} = \Delta SURP_{ex} / \text{Existing Storage Generation Size},$$

where Existing Storage Generation Size is the sum of the capacities of the individual storage units on the system that are not less than than 10 MW.

In this example, **DRF_{ex}** is 229/(73*4 + 10), or **0.758**.

3. Next we calculate the details of the Reference Storage Unit. The system storage has an average unit size of (73*4 + 10)/5 = 60 MW, and a storage volume of (1500+10)/ (73*4 + 10) = 5 hours. We assume that this unit takes the outage statistics of the storage type that makes up the majority of its capacity - in this case Pumped Hydro Storage. The Reference Storage Unit is therefore a Pumped Hydro Storage unit with a generation size of 60 MW and a storage volume of 5 hours.

   We get its de-rating factor (**DRF_{Ref}**) by adding the Reference Storage Unit to the system and noting the change in adequacy. However this has already been done to obtain the table of Initial Marginal De-rating Factors for Pumped Hydro Storage, since the Reference Storage Unit is considered to be a Pumped Hydro Unit. A value of 0.684 was obtained, so **DRF_{Ref} = 0.684.**

4. We can now calculate the Storage Adjustment Factor:

$$\mathbf{DRF_{Ex} / DRF_{Ref} = 0.758/0.684 = 1.108}$$

5. Finally, the table of the Initial Marginal De-rating Factors is multiplied by the Storage Adjustment Factor, giving the final DRFs[4] which are to be applied for the auction:

Table 2 Final de-rating factors for Pumped-Hydro storage units

Units Size	0.5 Hours	1 Hours	1.5 Hours	2 Hours	2.5 Hours	3 Hours	3.5 Hours	4 Hours	4.5 Hours	5 Hours
20	0.227	0.392	0.512	0.594	0.652	0.691	0.717	0.737	0.754	0.772
40	0.212	0.376	0.497	0.579	0.634	0.673	0.700	0.719	0.737	0.755
60	0.210	0.374	0.493	0.574	0.631	0.671	0.698	0.719	0.738	0.758
80	0.201	0.363	0.480	0.561	0.619	0.661	0.690	0.712	0.732	0.753
100	0.190	0.347	0.463	0.545	0.603	0.645	0.675	0.698	0.719	0.741

For the Other Storage technology class, the process is the same as above. The values of **DRF_{ref}** and **DRF_{ex}**, and hence the Storage Adjustment Factor, are unchanged. However the Initial Marginal De-rating Factor table would have different values, since the storage units we add to the system have different outage characteristics.

[4]While extremely unlikely, it is mathematically possible for this step to lead to DRFs which are greater than one. In this case the DRFs will be capped at 1 as per their definition in the Capacity Market Code C.1.1.2(f), *"a de-rating factor is a factor between zero and one ..."*

The above example is aimed to demonstrate the calculation of storage de-rating factors only. The values used are not intended for application outside of this example. In reality the above calculation is carried out for all Capacity Adequacy Portfolios (CAPs) at the least-worst regrets demand level, with results then averaged. However for simplicity the example only looks at one CAP.

A. Do participants have any comments on the methodology for calculating DRFs for storage units as described above?

4.4 Considerations for Consultation

4.4.1 New storage technologies

Energy storage technology, particularly battery technology, has developed considerably in recent years. As such it is quite possible that new storage capacity looking to enter the Capacity Auction will not be Pumped Hydro Storage. Currently, it is proposed that such generators will be assumed to have the average system wide outage statistics, and that their DRFs would be taken from the Other Storage table published in the IAIP. This is consistent with the approach for non-storage generation, where generators not fitting into an existing category will be assumed to have the average system wide outage statistics, with DRFs calculated on this basis.

B. In the absence of significant historical data, do participants consider it reasonable to apply system-wide outage statistics to new technologies (such as batteries)? If not, please provide alternative with justification.

4.4.2 Treatment of Units in between storage step sizes, or below the minimum storage step size

In the published DRF tables for storage units, values are given as a function of both generation size and energy storage volume. The storage volume is expressed as Hours of Storage, which is the amount of time the unit can generate at full capacity (i.e. Initial Capacity as defined in the CMC). At present, the smallest energy storage volume size at which DRF values are published is given as 30 minutes. This matches the Imbalance Settlement Period.

Many newer electricity storage technology types, such as batteries, may have lower storage volumes (in MWh) as a proportion of their generation capacity (in MW) compared to traditional Pumped Hydro storage units. As the number of hours of storage a unit has decreases, its contribution towards system adequacy drops substantially.

Currently, the methodology provides values for storage volumes as low as 30 minutes, with a 30 minute resolution between storage volume sizes. The TSO's intention is that units with storage volumes that are not a multiple of 30 minutes would use interpolation to determine their DRF. Specifically, if a unit does not have a storage capacity which is an exact multiple of 30 minutes, it should take the de-rating factors for the nearest half-hour storage volumes above[5] and below its storage size, and interpolate linearly between these.

The linear interpolation formula, assuming a 30 minute step size, is as follows:

[5] Units with a storage volume larger than the largest storage size listed in the published DRF tables would take their DRF from the largest volume listed. See section 4.4.4 for more details

$$DRF = ((T_{step}-\Delta t)*DRF_{below} + (\Delta t)*DRF_{above})/\ T_{step}, \textit{ where}$$

T_{step} = Step size in storage volume in minutes (presumed 30)
Δt = Additional minutes of storage volume the unit has compared to the storage volume step below it
DRF_{below} = De-rating factor value for the storage volume step just below the unit's storage volume
DRF_{above} = De-rating factor value for the storage volume step just above the unit's storage volume

Two examples are given below, based on the figures in Table 2.

i. <u>A 40 MW unit with 15 minutes storage.</u> Any pure storage unit with a storage volume of 0 clearly has a de-rating factor of zero, so DRF_{below} = 0 in this case. The DRF for a unit with 15 minute storage volume would therefore be half the DRF value applied to a similar unit with 30 minutes storage. In this case, the DRF is 0.5 * 0.212, or **0.106**. The units de-rated capacity is 4.240 MW
ii. <u>A 100 MW unit with 96 minutes storage.</u> This unit's storage volume, at 1 hours and 36 minutes lies between the 1.5 hour and 2 hour data points. We therefore interpolate between these values.

    T_{step} = 30
    Δt = 6 [i.e. 1 hours 36 minutes – 1 hours 30 minutes]
    DRF_{below} = 0.463
    DRF_{above} = 0.545

    Applying these values to the formula gives **0.479.** The unit's de-rated capacity is **47.900** MW.

This approach differs to that used for Unit Size values, where size ranges are defined for all units clearly falling within a range. However, the difference in DRF between adjacent storage steps (i.e. across the DRF tables) is far greater than the difference in DRF between adjacent Unit Size values. As such, using defined ranges would lead to undesirable boundary effects between adjacent storage steps.

The above option is the proposed approach. It reflects the relationship between a unit's storage volume and its contribution towards system adequacy with reasonable accuracy, without adding undue complexity to the application process for auction participants.

Some alternative approaches were considered for calculating the DRFs for units with storage volumes in between the published storage step sizes. These are discussed in the following paragraphs.

One approach that could be taken is **simple rounding** of a unit's storage volume to the nearest step size i.e. to the nearest 30 minutes. This would mean the 0.5 hour DRF value should cover units with between 15 and 45 minutes of storage for simple rounding (or between 30 and 59 minutes if rounding down). A unit with 10 minutes of storage would be given a DRF of 0, since this is the DRF of a unit with 0 minutes storage.

A similar approach that could be taken is **rounding down** of a unit's storage volume to the nearest step size. This would mean the 0.5 hour DRF value should cover units with between 30 and 59 minutes of storage. In this case any unit with up to 29 minutes of storage would be given a DRF of 0, since this is the DRF of a unit with 0 minutes storage.

The **simple rounding** and **rounding down** approaches effectively excludes units with less than 15 minutes storage from the capacity market (or 30 minutes if rounding down). This could be considered acceptable, as such units may have very limited value from a capacity provision perspective, and may be more suited to provision of other system services for which they will be rewarded appropriately.

It also would equate the de-rating factors of units with storage volumes up to 29 minutes apart i.e. units with storage volumes at the start and end of the 30 minute range would be given the same DRFs, all else being equal. For units with smaller storage volumes this approximation becomes less valid, as the contribution such units make to system adequacy can in reality be quite different. This is reflected in Figure 3, where there is a considerable gap in the DRFs obtained from using the bottom two curves, even though they only differ by 30 minutes of storage volume.

Two examples are given below, based on the figures in Table 2.

i. A 40 MW unit with 15 minutes storage. With simple rounding, the unit is treated as a 40 MW unit with 30 minutes of storage (since 15 is 0.5 of 30, and 0.5 rounds up to 1). The DRF is **0.212** and the unit's de-rated capacity is 8.480 MW. With downward rounding the DRF is 0, as is the unit's de-rated capacity.
ii. A 100 MW unit with 96 minutes storage. This unit's storage volume, at 1 hour and 36 minutes, is treated as if it were simply 1.5 hours. The DRF is **0.463** and the unit's de-rated capacity is **46.300** MW

Another option would be to adjust the capacity a storage unit can submit into the capacity market auction, using a parameter called **Adjusted Storage Unit Capacity.** The value of this parameter would be set so that its storage volume can be expressed as the next storage step size multiplied by the **Adjusted Storage Unit Capacity.**

Adjusted Storage Unit Capacity = Initial Capacity * Storage Volume/T_{above}, *where*

Storage Volume = Storage Volume size of the unit (given in minutes)
T_{above} = Smallest storage step size that is larger than Storage Volume (given in minutes)

This calculation is best suited to units with a storage volume of less than 30 minutes; however it could in theory be applied to any unit

For a unit with a storage volume less than 30 minutes, its Adjusted Storage Unit Capacity is effectively double its storage volume in MWh. The de-rating factor is calculated based on the Adjusted Storage Unit Capacity with a storage volume of T_{above}. To get the de-rated capacity of the unit, this de-rating factor is applied to its Adjusted Storage Unit Capacity.

Two examples are given below, based on the figures in Table 2.

i. A 40 MW unit with 15 minutes storage. This unit can deliver 20 MW over a 30 minute period. It's Adjusted Storage Unit Capacity = 40 * 15/30 = 20 MW. It therefore gets a de-rating factor of .227, which is applied to its Adjusted Storage Unit Capacity of 20 MW, giving a de-rated capacity of 4.54 MW
ii. A 100 MW unit with 96 minutes storage. This unit's storage volume is 1 hours and 36 minutes. The next step (T_{above}) is therefore 2 hours. The **Adjusted Storage Unit Capacity = 100 * 96/120 = 80 MW.** It therefore gets a de-rating factor for an 80 MW unit with 2 hours of storage, which is

.561. This is applied to its Adjusted Storage Unit Capacity of 80 MW, giving a de-rated capacity of **44.880** MW

C. Regarding Storage Units with Storage Volume sizes that are not a multiple of 30 minutes: Do participants have any comments on the TSO's preferred methodology for calculating DRFs for such storage units, i.e. interpolating between storage sizes? What other options do they believe may be more appropriate?

4.4.3 Applying downward tolerance for storage units and other energy limited units

Commitments to deliver system services may lead to storage units and other energy-limited units expending all of their energy in a short time-frame, leaving them exposed during other trading periods. From a system security perspective, it would be undesirable to have a unit potentially exposed to Capacity Market penalties for meeting their obligations in the provision of system services. As such there may be an argument for allowing such units to apply a DECTOL value (i.e. a downwards adjustment) to the capacity they submit into the Capacity Market auction. They could then reduce their exposure to difference payments in order to reflect their commitments to system services provision.

In addition, 'Other Storage' units that sit outside a defined Technology Class – currently any storage which is not Pumped Hydro – will be allocated the System Wide outage statistics, which may not be reflective of their expected performance. This is similar to how Demand Side Units are currently treated, and application of a volunatary DECTOL to Other Storage units would be consistent with the treatment of DSUs.

D. Should storage units be allowed to apply a DECTOL to their De-rated Capacity? Please provide arguments to support your response.

4.4.4 Largest Energy Storage Volume used in DRF tables

In the published DRF tables for storage units, DRF values are provided as a function of energy storage volume. The storage volume is expressed as Hours of Storage, which is the amount of time the unit can generate at full capacity (i.e. Initial Capacity as defined in the Capacity Market Code). At present, the largest energy storage volume size at which DRF values are published is given as 6 hours or more. This figure is based on the DRF of a unit with 6 hours storage. This means that a unit with 10 hours of storage would receive the same DRF as a unit with 6 hours of storage, all else being equal.

As storage volume sizes increases, it becomes less of a constraint on a unit's contribution to system adequacy, and DRFs should converge. As such, it is appropriate to group the DRFs for units with larger storage volumes.

The TSOs do not anticipate the entry of units with energy storage volumes of 6.5 hours or greater into the Capacity Market auction in the near future. Should this change, it may be required to review the approach above.

E. Should specific DRF values be published for units with energy storage volumes of 6.5 hours or greater? Are participants aware of potential projects that might make such a change appropriate?

5 Other Energy & Run-hour Limited Generation

Energy storage devices such as pumped hydro storage and batteries usually have clearly defined storage durations and charging efficiencies that set their energy limitations and impact on system adequacy. There can also be energy/run-hour limitations for capacity providers that are not part of the storage technology class. These include hydro units, Demand Side Units and emissions limited generators. The impact of these limitations on system adequacy can be more difficult to quantify, but given the potential cumulative impact of these limitations on system adequacy it may be appropriate to adjust the De-rating Factors for units affected by such limitations.

It is not proposed to create extra technology classes for these units; however a downward adjustment of De-rating Factors may be considered. The topic is discussed below and we would welcome any feedback respondents may have on the issue and any supporting evidence respondents can provide to justify their views.

5.1 Emissions Limited or Run-hour Limited Generation

The Industrial Emissions Directive and associated Transitional National Plans may restrict the operation of some units in I-SEM. The cumulative impact of these restrictions on system adequacy is potentially significant. This is especially the case in the new market where only those successful in the capacity auction will receive capacity payments. The impact of these limitations will depend on the unit's emissions abatement technology, operating license and jurisdiction.

Policy trends in Europe seem to be moving toward more onerous conditions on the participation of generators with relatively high CO_2 emission rates in Capacity Markets.[6] It may be pertinent to consider a downward adjustment (either mandatory or voluntary), perhaps through the application of a DECTOL, or an adjustment factor to De-rating Factors for such units in the I-SEM Capacity Market. This downward adjustment would reflect an estimation of how emissions limits could reduce the unit's contribution to security of supply.

A voluntary DECTOL would allow a unit to make an estimate of its expected run-hours in a particular year, accounting for any emissions restricitions, and adjust their exposure in the capacity market accordingly. Since run-hours are linked to a unit's bidding behaviour in the market, the unit owner will generally be in a better position to estimate them than the TSOs.

One manner how a mandatory adjustment would work is as follows. A unit would provide the TSO with an estimate of its maximum run hours for a particular capacity year. If this is below a threshold set by the RAs, this would be converted into a scaling factor, for example by dividing by the threshold. The threshold could for example be the number of weekday peak hours in the winter period – e.g. 4 hours per weekday in months November through March. This scaling factor would then apply to the unit's DRF.

As an example, a unit states that, due to emissions restrictions, its running will be limited to 170 hours. This is compared to the number of winter peak hours, around 340. It will then have a scaling factor of 0.5 applied to its De-rating Factor.

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[6] See the European Commission's Clean Energy Package and UK's DEFRA consultation on imposing emissions limits on capacity market participants

F. **Do participants consider a unit's run-hour limitations (due to emission restrictions or otherwise) should be reflected in the Capacity Market Auction? If so, what mechanisms should be applied. If not, please provide rationale.**

5.2 Demand Side Units

Currently some Demand Side Units set significant limitations for their operation, such as setting a maximum duration (or Maximum Down Time) for their demand reduction. Under Grid Code rules this can be as low as two hours. As with storage units, a unit with these characteristics does not deliver the same benefit to adequacy as a unit that does not limit its dispatch.

One approach would be to treat such units in a manner consistent with storage units. A DSU's Maximum Down Time would be considered equivalent to a storage unit's Hours of Storage. For DRF calculation purposes, DSUs are currently treated as a new technology and are given the System Wide outage characteristics. DSUs with a Maximum Down Time of less than 6 hours could take their DRFs from the Other Storage de-rating curves.

For example, consider a DSU with a registered capacity of 35 MW and a Maximum Down Time of 3 hours. Taking the Other Storage De-rating curve published in the IAIP for the 2018/19 T-1 auction would give a de-rating factor of 0.730 for that unit.

Table 3 De-rating factors for other storage units, as published in the IAIP for the 2018/19 T-1 auction

	Hours of Storage											
Unit Size (MW)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0 or greater
1 -> 10	0.251	0.429	0.556	0.646	0.708	0.751	0.780	0.801	0.819	0.838	0.862	0.888
11 -> 20	0.244	0.422	0.550	0.640	0.701	0.744	0.773	0.794	0.812	0.832	0.856	0.881
21 -> 30	0.237	0.415	0.544	0.633	0.695	0.737	0.766	0.787	0.806	0.826	0.849	0.875
31 -> 40	0.231	0.409	0.538	0.627	0.688	0.730	0.759	0.781	0.799	0.819	0.843	0.868

G. **Do participants have any comments on the proposed approach for de-rating DSUs with limited Maximum Down Time?**

6 Conclusion

This paper expands on the methodology for determining the de-rating factors for generator units with energy storage, which was previously presented in Appendix SEM-17-040b. Additional issues relating to the calculation of De-rating Factors for storage units are also examined.

This paper also considers how a limitation to run hours[7] should impact on the calculation of a unit's de-rating factor.

The following questions are posed to participants:

A. **Do participants have any comments on the methodology for calculating DRFs for storage units as described in this paper?**
B. **In the absence of significant historical data, do participants consider it reasonable to apply system-wide outage statistics to new technologies (such as batteries)? If not, please provide alternative with justification.**
C. **Regarding Storage Units with Storage Volume sizes that are not a multiple of 30 minutes: Do participants have any comments on the TSO's preferred methodology for calculating DRFs for such storage unit, i.e. interpolating between storage sizes? What other options do they believe may be more appropriate?**
D. **Should storage units be allowed to apply a DECTOL to their De-rated Capacity? Please provide arguments to support your response.**
E. **Should specific DRF values be published for units with energy storage volumes of 6.5 hours or greater? Are participants aware of potential projects that might make such a change appropriate?**
F. **Do participants consider that a unit's run-hour limitations (due to emission restrictions or otherwise) should be reflected in the Capacity Market Auction? If so, what mechanisms should be applied. If not, please provide rationale.**
G. **Do participants have any comments on the proposed approach for de-rating DSUs with limited Maximum Down Time?**

[7] E.g. due to emissions restrictions, or approaching end of life